

What is claimed is:

1. A method for controlling wheel slip across a differential mechanism of a motor vehicle having a steering angle and a steering direction, the differential mechanism driven by a driveshaft and having first and second rotating output shafts driveably connected to the wheels and connectable by a clutch that is activated by a magnetic field of variable strength to change a torque capacity of the clutch, the method comprising the steps of:
 - determining the steering angle and the direction of the steering angle;
 - determining a target speed of the output shafts that corresponds to a current driveshaft speed, steering angle and steering direction;
 - determining the speeds of the output shafts;
 - comparing the speeds of the output shafts and the target speeds to determine whether wheel slip is present; and
 - in response to the comparison, adjusting the magnitude of the field strength to increase the torque capacity of the clutch and control the speed of the output shafts such that the wheel slip is reduced.
2. The method of claim 1, further comprising the step of :
 - reducing the magnitude of torque to be transmitted by the clutch in comparison to the magnitude of torque carried by the two output shafts.
3. The method of claim 1, wherein the differential includes a first control shaft driven by the first output shaft, and a second control shaft driven by the second output shaft, the method further comprising the steps of:
 - locating the clutch in a torque path between the first and second control shafts such that the first and second control shafts are connectable by the clutch;
 - reducing a magnitude of torque transmitted to the first control shaft in comparison to a magnitude of torque carried by the first output shaft; and

reducing a magnitude of torque transmitted to the second control shaft in comparison to a magnitude of torque carried by the second output shaft.

4. The method of claim 1, wherein the step of adjusting the magnitude of
5 the field strength, further includes the steps of:

locating the clutch in a torque path between the first and second output shafts such that the first and second output shafts are connectable by the clutch;

placing magnetic powder in a space located in the clutch in the torque path between the first output shaft and second output shaft such that a magnetic field passes
10 through the magnetic powder;

producing a variable torque capacity through the clutch between the first and second output shafts by adjusting the magnitude of the magnetic field.

5. The method of claim 1, wherein the step of adjusting the magnitude of
15 the field strength, further includes the steps of:

producing electric current in the coil from a PWM signal having a variable duty cycle whose magnitude produces a reduction in wheel slip.

6. The method of claim 1, further comprising the step of:

20 locating a coil in the clutch with respect to the location of the magnetic powder such that a magnetic field passes through the magnetic powder; and

wherein the step of adjusting the magnitude of the field strength further includes the step of producing electric current in the coil from a source of D.C. electric power whose magnitude produces a reduction in wheel slip.

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7. The method of claim 1, wherein the step of adjusting the magnitude of the field strength, further includes the step of:

adjusting a moveable permanent magnet whose location produces a reduction in wheel slip.

8. A method for controlling wheel slip across a differential mechanism of a motor vehicle having a steering angle and a steering direction, the differential mechanism driven by a driveshaft and having first and second rotating output shafts driveably connected to the wheels and connectable by a clutch that is activated by a magnetic field of variable strength to change a torque capacity of the clutch, the method comprising the steps of:
- determining the steering angle and the direction of the steering angle;
 - determining a target speed of the output shafts that corresponds to the current driveshaft speed, steering angle and steering direction;
 - determining the speeds of the output shafts;
 - reducing the magnitude of torque to be transmitted by the clutch in comparison to the magnitude of torque carried by the first and second output shafts;
 - comparing the speeds of the output shafts and the target speeds to determine whether wheel slip is present; and
 - in response to the comparison, adjusting the magnitude of the field strength to increase the torque capacity of the clutch and control the speed of the output shafts such that the wheel slip is reduced.
9. The method of claim 8, wherein the differential includes a first control shaft driven by the first output shaft, and a second control shaft driven by the second output shaft, the method further comprising the steps of:
- locating the clutch in a torque path between the first and second control shafts such that the first and second control shafts are connectable by the clutch;
 - reducing a magnitude of torque transmit to the first control shaft in comparison to a magnitude of torque carried by the first output shaft; and
 - reducing a magnitude of torque transmit to the second control shaft in comparison to a magnitude of torque carried by the second output shaft.

10. The method of claim 8, wherein the step of adjusting the magnitude of the field strength, further includes the steps of:

locating the clutch in a torque path between the first and second output shafts such that the first and second output shafts are connectable by the clutch;

5 placing magnetic powder in a space located in the clutch in the torque path between the first output shaft and second output shaft such that a magnetic field passes through the magnetic powder;

producing a variable torque capacity through the clutch between the first and second output shafts when the coil is energized.

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11. The method of claim 10, wherein the step of adjusting the magnitude of the field strength, further includes the steps of:

locating the clutch in a torque path between the first and second control shafts such that the first and second control shafts are connectable by the clutch;

15 placing magnetic powder in a space located in the clutch in the torque path between the first output shaft and second output shaft;

locating a coil in the clutch with respect to the location of the magnetic powder such that a magnetic field passes through the magnetic powder; and

20 producing a variable torque capacity through the clutch between the first and second control shafts when the coil is energized.

12. The method of claim 8, wherein the step of adjusting the magnitude of the field strength, further includes the steps of:

25 producing electric current in the coil from a PWM signal having a variable duty cycle whose magnitude produces a reduction in wheel slip.

13. The method of claim 8, further comprising the step of:

locating a coil in the clutch with respect to the location of the magnetic powder such that a magnetic field passes through the magnetic powder; and

wherein the step of adjusting the magnitude of the field strength further includes the step of producing electric current in the coil from a source of D.C. electric power whose magnitude produces a reduction in wheel slip.

5 14. The method of claim 8, wherein the step of adjusting the magnitude of the field strength, further includes the steps of:

 adjusting a moveable permanent magnet whose location produces a reduction in wheel slip.

10 15. A system for controlling wheel slip of a motor vehicle having wheels, a steering angle and a steering direction, comprising:

 a differential mechanism driven by a driveshaft, and including two rotating output shafts driveably connected to the wheels;

 a clutch including a first element driveably connected to the first output shaft, a
15 second element driveably connected to the second output shaft, a chamber at least partially bounded by the first element and second element, magnetic powder located in the chamber, an electromagnetic coil producing a magnetic field of variable strength passing through the chamber and magnetic powder and changing a capacity of the clutch to transmit torque between the first and second output shafts as the field
20 strength changes;

 sensors producing signals representing the speed of the output shafts, the steering angle, and the direction of the steering angle; and

 a controller receiving as input the signals produced by the sensors, determining a target speed of the output shafts that corresponds to a driveshaft speed, steering
25 angle and steering direction, comparing the speed of the output shafts and the target speeds to determine whether wheel slip is present, and adjusting the magnitude of the field strength to control the speed of the output shafts and reduce wheel slip.

 16. The system of claim 15, further comprising:

means for reducing the magnitude of torque transmitted by the clutch in comparison to the magnitude of torque carried by the two output shafts.

17. The system of claim 15, further comprising:

- 5 a first control shaft driveably connected to the first element;
- a second control shaft driveably connected to the second element;
- a first torque reduction mechanism driveably connected to the first output shaft and first control shaft for reducing the magnitude of torque carried by the first control shaft in comparison to the magnitude of torque carried by the first output shaft; and
- 10 a first torque reduction mechanism driveably connected to the second output shaft and second control shaft for reducing the magnitude of torque carried by the second control shaft in comparison to the magnitude of torque carried by the second output shaft.

18. The system of claim 17, wherein:

- 15 the first torque reduction mechanism further comprises a pinion secured to the first output shaft, a gear secured to the first control shaft, driveably connected to the pinion and having a smaller diameter and fewer gear teeth than the pinion; and
- the second torque reduction mechanism further comprises a second pinion
- 20 secured to the second output shaft, a second gear secured to the second control shaft, driveably connected to the second pinion and having a smaller diameter and fewer gear teeth than the first pinion.

19. The system of claim 15, further comprising a controller causing an

- 25 electric current to be applied to the coil, the current being in the form of a PWM signal having a variable duty cycle.

20. The system of claim 15, further comprising a controller causing an electric current to be applied to the coil, the current being in the form of a D.C. signal having a variable magnitude.

5 21. The system of claim 15, further comprising a controller causing an electric current to be applied to a moveable permanent magnet, the current being in the form of a d. c. signal that moves the magnet to cause a change in the magnetic field.

22. The system of claim 15, wherein the chamber has a relatively large
10 width along a length of the first element and second element, and the chamber has a relatively narrow thickness between the first element and the second element.

23. The system of claim 15, wherein the chamber has a narrow thickness between the first element and the second element.

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24. The system of claim 15, wherein the magnetic powder is in the form of gas-atomized, spherical particles of 410 low carbon stainless steel, the particles having a size in the range 1-250 microns.

20 25. The system of claim 15, wherein the magnetic powder is in the form of ferromagnetic particles.

26. A clutch for changing a magnitude of transmitted torque, comprising:
first and second rotating control shafts;
25 a first element driveably connected to a first control shaft;
a second element driveably connected to the second output shaft;
a chamber at least partially bounded by the first element and second element;
magnetic powder located in the chamber; and

an electromagnetic coil producing a magnetic field of variable strength passing through the chamber and magnetic powder and changing a capacity of the clutch to transmit torque between the first and second control shafts as the field strength changes.

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27. The clutch of claim 26, wherein the magnetic field of variable strength is produced by a permanent magnet.

28. The clutch of claim 26, wherein the magnetic field of variable strength is
10 produced by a combination of a permanent magnet and an electromagnetic coil.

29. The clutch of claim 26, wherein the chamber has a relatively large width along a length of the first element and second element, and the chamber has a relatively narrow thickness between the first element and the second element.

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30. The system of claim 26, wherein the chamber has a narrow thickness between the first element and the second element.

31. The system of claim 26, wherein the magnetic powder is in the form of
20 gas-atomized, spherical particles of 410 low carbon stainless steel, the particles having a size in the range 1-250 microns.

32. The system of claim 26, wherein the magnetic powder is in the form of ferromagnetic particles.

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